

Salmon

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Two species of salmon—chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*)—are commonly found in the Gulf of the Farallones. Chinook salmon fishing is the activity that brings the most people out on the waters of the gulf (fig. 1). In 1995, the chinook fishery in the gulf was valued at more than \$24 million.

Chinook (or king) salmon are key predators in the gulf (fig. 2), and their distribution and occurrence are related to their seasonal diet cycle. Chinook salmon found in the gulf are mostly 3-year-old fish that are preparing to enter the Sacramento River system, where they will spawn and then die. After the eggs hatch the following spring, the juvenile salmon will grow for 7 months in freshwater. They then migrate to the ocean, where they will live for 2 years before returning to the gulf. Coho (or silver) salmon along the California coast are listed as a threatened species under the Endangered Species Act, and their capture has been prohibited since 1993. Native-run (versus hatchery) chinook salmon are also a candidate for a threatened-species listing.

During their last year of life, most chinook salmon that spawn in the Sacramento River system have a diet cycle in which they feed on different prey in different locations (fig. 3). It is fairly consistent from year to year, except when oceanic conditions are very unusual, such as in El Niño years (see chapter on Current Patterns Over the Continental Shelf and Slope). The following is a general outline of this cycle: It begins in February, when 3-year-old chinook salmon move from the open ocean into the Gulf of the Farallones and feed close to shore on Pacific herring and northern anchovy. In April, chinook start to move offshore, feeding on euphausiid shrimp (krill) and crab larvae. From May through June, chinook are feeding on juvenile rockfish and euphausiids offshore near the Farallon Islands. In July, chinook return nearshore to feed exclusively on anchovy. They remain there until September, when they begin to migrate into San Francisco Bay and up into the Sacramento River system to spawn. In February, the next year's 3-year-old chinook begin to enter into the gulf, and the diet cycle begins again.

When 3-year-old chinook salmon move into the Gulf of the Farallones in February and March, they are found off the Golden Gate from Bolinas Point in the north to Point San Pedro in the south. While in this area they feed almost equally on Pacific herring and anchovies. The herring have just migrated back to their feeding grounds outside of the Golden Gate from San Francisco Bay, where they spawned from November through February. After spawning, the herring are especially vulnerable to predation by chinook because they are generally weakened. Anchovies are also prey of salmon during this period. In February and March, anchovies are gathering in nearshore waters before moving into San Francisco Bay beginning in April.

April is a time of transition for the chinook between the earlier nearshore feeding and the offshore feeding that occurs in May and June. Chinook are found from north of the Golden Gate to Point Reyes and offshore to the Farallon Islands. They feed on invertebrates during this period, largely the euphausiid shrimp *Thysanoessa spinifera*. This euphausiid is a large coastal-dwelling species. Euphausiids are taken as prey from surface and subsurface swarms that occur over a wide area of the gulf during April and May. The pink to orange color of salmon flesh during this period is caused by a carotenoid pigment in the skeleton of the euphausiid (for more about euphausiid shrimp, see chapter on Krill). This flesh color has become so popular that now there are fisheries for euphausiids, which are freeze-dried and fed to pen-reared salmon as a finishing product to produce this color.

For a brief 2- or 3-week period in April, the chinook's diet is dominated by the megalopa larvae of the Dungeness crab (*Cancer magister*) (see chapter on Free-Floating Larvae of Crabs, Sea Urchins, and Rockfishes). These larvae are the last pelagic (free-floating or swimming) stage before the crabs sink to the bottom and take on their adult shape. More than 7,000 Dungeness megalopa have been found in a single chinook stomach.

In May and June, chinook start feeding on euphausiids and juvenile rockfish offshore near the Farallon Islands. These rockfish are late pelagic-stage fish that as adults will migrate to bottom habitats. In years when juvenile rockfish are abundant, they are the preferred prey and dominate the chinook diet during these months, whereas in low-abundance years, chinook feed mainly on euphausiids.

Sometime between mid-June and mid-July, the chinook abruptly move from near the Farallon Islands to directly in front of the Golden Gate, the so-called "middle grounds." Here, chinook feed exclusively on anchovies. The anchovies had moved into San Francisco Bay in May and June to begin spawning in the warmer water. After June, when the water in the gulf warms up because of the absence of cold upwelled water, anchovies move out of the bay and into the gulf where they continue spawning into October. The seasonal disappearance of juvenile rockfish offshore and the concentration of anchovies near shore lead the chinook to congregate in front of the Golden Gate. Chinook remain in this area until October, but in lower and lower concentrations as they move up the Sacramento River system to spawn.

Chinook salmon depend on aggregations of prey that are available only for limited lengths of time and in separate locations. This dependence on these traditional prey complexes is shown by the disruption of salmon populations by strong El Niños. During strong El Niño years, the normal sequences of prey do not develop because the large increase in ocean temperature disrupts the prey's normal behavior. Because the traditional prey complexes do not form, the aggregations of salmon that feed on these prey do not form. As a result chinook of a given length weigh much less than normal, California's commercial salmon catch drops severely, and the recreational catch is far below average.

Further Reading

- Boydston, L.B., Hallock, R.J., and Mills, T.J., 1992, Salmon, in Leet, W.L., Dewees, C.M., and Haugen, C.H., eds., California's living marine resources and their utilization: Berkeley, University of California Sea Grant Publication UCSGEP-92-12, p. 60-65.
- Healy, M.C., 1991, Life history of chinook salmon (*Oncorhynchus tshawytscha*), in Croot, C. and Margolis, L., eds., Pacific salmon life histories: Vancouver, British Columbia, Canada, University of British Columbia Press, p. 311-394.



Figure 1. Chinook salmon fishing is the activity that brings the most people out on the waters of the Gulf of the Farallones. This large salmon was caught in the gulf. (Photograph from National Marine Fisheries Service.)



Figure 2. A chinook salmon (*Oncorhynchus tshawytscha*). Most chinook salmon found in the Gulf of the Farallones are 3-year-old fish that are returning from the open ocean and preparing to enter the Sacramento River system, where they will spawn and then die. (Photograph from Regulatory Fish Encyclopedia, Office of Seafood and Office of Regulatory Affairs, U.S. Food and Drug Administration, 1993–98.)

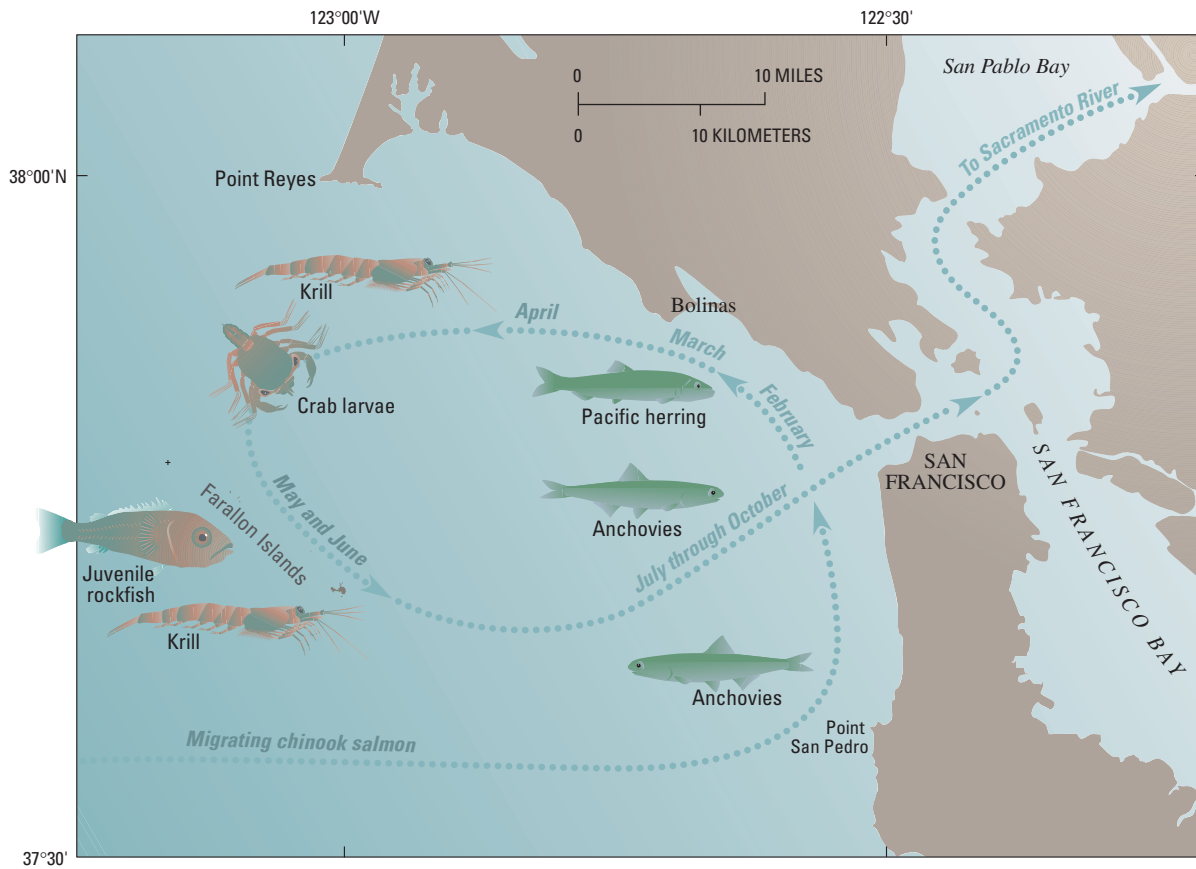


Figure 3. Diet cycle of chinook salmon (*Oncorhynchus tshawytscha*) in the Gulf of the Farallones. Three-year-old chinook salmon returning from the open ocean move into the gulf in February and March and feed on Pacific herring and anchovies off the Golden Gate from Bolinas Point in the north to Point San Pedro in the south. In April, they feed on invertebrates, largely the euphausiid shrimp (krill) *Thysanoessa spinifera*. The pink to orange color of salmon flesh during this period is due to a carotenoid pigment in the exoskeleton of the krill. For a brief 2- or 3-week period in April, the chinook's diet is dominated by larvae of the Dungeness crab (*Cancer magister*). In May and June, chinook start feeding on krill and juvenile rockfish near the Farallon Islands. Sometime between mid-June and mid-July, the chinook abruptly move from near the Farallon Islands to directly in front of the Golden Gate, the so-called "middle grounds." Here, chinook feed exclusively on anchovies. Chinook remain in front of the Golden Gate until October, but in lower and lower concentrations as they move up the Sacramento River system to spawn. The following February, the next year's 3-year-old chinook begin to enter into the gulf, and the cycle begins again.